79-9.3

# AIR POLLUTION CONTROL CONSIDERATIONS

# IN THE COLD LAKE PROJECT

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in the Cold Lake Project

Presented to:

PNWIS - APCA 1979 CONFERENCE

Edmonton, Alberta
November, 1979

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## INTRODUCTION

The proposed Esso Resources Canada Limited Cold Lake Project will be one of the first commercial scale schemes to recover bitumen from a deeply buried tar sands deposit by in-situ technology. An average of 160,000 B/D of bitumen will be recovered from the Clearwater formation of the Cold Lake oil sands deposit by the in-situ process of steam stimulation. The produced bitumen will be upgraded on-site to about 141,000 B/D of a widely marketable, low sulphur crude.

The proposed Project has been the subject of an intensive environmental impact assessment and review since September, 1977. Potential impacts, on soils, vegetation, water, air, faunal and historical resources have been identified and control features and mitigation measures developed [1,2]. The Alberta Energy Resources Conservation Board has given a preliminary recommendation for project approval. A final Cabinet decision is anticipated by the end of 1979.

This paper will provide a brief overall description of the Project. An overview of the major air pollution concerns will then be presented along with a summary description of the facilities proposed to control and monitor potential emissions.

## PROJECT DESCRIPTION

The proposed Project will be located approximately 11 km west of Cold Lake in northeastern Alberta. The development area will cover about 143 $km^2$ within the overall lease area. Site preparation is scheduled to begin in 1981 with production of upgraded crude to begin in 1986. The Project as shown in the simplified schematic of Figure 1 involves three major components:

1. A production facility designed to produce an average of 25.4 x $10^3 m^3/d$ (160,000 B/D) of bitumen from the Clearwater formation of the Cold Lake oil sands deposit by the in-situ process of steam stimulation.

2. An upgrading facility designed to convert the produced bitumen to 22.3 x $10^3 m^3/d$ (141,000 B/D) of widely marketable upgraded crude.

3. A steam generation/utilities complex with attendant water supply and treatment facilities designed to serve both the production and upgrading facilites.

### A. In-Situ Recovery Process

The in-situ production process consists of injecting steam into the reservoir for 1-2 months to reduce the bitumen viscosity.

Bitumen is then produced from the same well for about 3-6 months. This "stimulation" cycle is repeated several times over the life of a well.

A total of about 8300 wells will be required over a 25 year Project life with about 2200 wells in operation at any given time. Surface disturbance will be minimized by employing a cluster drilling concept which will locate 20 directionally drilled wells on a relatively small pad. In this manner only about 16 percent of the development area will be disturbed by surface facilities. A sketch of the projected Cold Lake development after 7 years operation is shown in Figure 2 as an example of the proposed stage wise development.

Production from the wells consists of a mixture of bitumen and water emulsion, free water and gas. The mixture from each well grouping (satellite) is routed to one of two central production plants (Fieldgates) designed to separate gas and water from the produced bitumen.

The bitumen is delivered to the Upgrader, while the produced water is treated for reuse in the steam generators and the gas is used as fuel.

B. Upgrading Process

The objective of the upgrading process is to convert the heavy, viscous raw bitumen to a widely marketable crude which can be processed by existing Canadian refineries to meet market demands.

The two basic approaches to converting bitumen to an upgraded crude are carbon removal and hydrogen addition. For each of these approaches, a number of commercially proven processes exist. A carbon removal process known as FLEXICOKING[3] has been selected as the process best suited for this Project.

This process combines conventional fluid coking with coke gasification and sulphur removal. The FLEXICOKING process converts virtually all of the heavy bitumen to light products and gas. Carbon removal is in the form of coke, which is gasified into low Joule coke gas. The coke gas is then desuphurized and consumed as fuel for steam generation and process heat. Approximately 98 percent of the coke yield is gasified, leaving about 86 t/d of high metals content purge and fine coke which will be sold, if possible, or disposed of in a landfill operation.

With respect to hydrogen addition, the liquid products from the FLEXICOKING process will be subjected to hydrotreating. Hydrotreating utilizes hydrogen in the presence of catalysts to extract sulphur and nitrogen while it stabilizes the products by saturating the olefins and some of the aromatics. Hydrogen will be generated on site by steam reforming of purchased natural gas.

The Upgrader contains extensive sulphur recovery facilities. These include amine scrubbing systems to remove $H_2S$ from the low

Joule and hydrotreating gases and 3 stage Claus Recovery Plants followed by hydrogeneration/absorption Tail Gas Cleanup Units to convert the $H_2S$ to elemental sulphur. The sulphur removal facilites will be described in more detail later.

Tankage is required at all steps in the upgrading process to assure adequate feed to the various units and to balance flows. The various components from the process units will be blended into a marketable upgraded crude for pipeline shipment. Approximately 477,000 $m^3$ (3 million barrels) of storage will be provided. All tankage will be diked for full containment of the product. Also included on the site will be an administrative building, laboratory, and buildings for the mechanical maintenance facilites.

C. Steam Generation/Utility Plant

The Steam Generation/Utility Plant includes facilities for steam generation, water supply and treatment, electrical and other utilities (compressed air, fire fighting facilities and sewage treatment).

The total daily water requirement for the Project is estimated at 143,000 $m^3/d$ (900,000 bpd); however, through water recycling, fresh water makeup requirements are reduced to about 93,000 $m^3/d$ (584,000 bpd). The fresh water makeup source for the Project will be the North Saskatchewan River.

The low Joule gas produced from the upgrading facility, gas produced with the bitumen and fuel gas generated in the Upgrader will be used to fire the boilers for steam generation. However, these fuel sources are insufficient to meet the total fuel requirements. Coal, natural gas and liquid product were considered as the balancing fuel in the utility plant. The AERCB has recommended that coal be utilized for this requirement.

Aqueous wastes meeting the Alberta refinery waste water effluent guidelines will be discharged into surface waters. The remainder will be disposed of by deep well injection into the McMurray and/or Cambrian formation which underly the bitumen producing zone.

Electrical power requirements will be purchased from the local grid system.

ENVIRONMENTAL PROTECTION FACILITIES

The major air pollution concerns in the Cold Lake Project are generally similar to those experienced in conventional refineries. These include the potential emission of sulphur oxides, hydrocarbons, odours, particulates, noise and fog.

A. Sulphur Emission Control

The proposed sulphur recovery facilities are shown in the simplified flow diagram, Figure 3.

The maximum emission guideline for the Cold Lake Project has been established at 3.2 t $SO_2/10^3m^3$ (0.5 LT $SO_2$/MB) of bitumen feed for normal operations and an emergency conditions level of 4.8 t $SO_2/10^3m^3$ (0.75 LT $SO_2$/MB) of bitumen feed. A sulphur balance for the total Project showing the sulphur inputs as well as a summary of unrecovered sulphur sources is detailed in Table 1. It is noted that only 39 t/d of sulphur from a total input of 1155 t/d are emitted to the atmosphere under normal operation.

(i) $H_2S$ Recovery

As shown in Figure 3, sulphur product is recovered from three $H_2S$ sources, i.e. scrubbing of low Joule gas, scrubbing of the sour gases from the Hydrotreaters and Light Ends Unit, and from the Sour Water Strippers.

Treatment of low Joule gas occurs in two parellel trains each using MDEA (Methyl-diethanolamine) as the solvent. In this process, sulphur is recovered in the form of $H_2S$ by amine absorption/regeneration. Each train consists of one absorber tower and one regeneration tower.

MDEA was selected as a solvent in preference to other amines because it provides good selectivity for $H_2S$ in the presence of $CO_2$ and good sulphur removal. The $H_2S$ level in the scrubbed low Joule gas will be 150 ppm.

The $H_2S$ produced from hydrotreating as well as that originating from the Light Ends Unit is scrubbed from the gases with conventional amine treating using DEA (Diethanolamine) as the solvent.

(ii) Claus Sulphur Recovery Plants

The $H_2S$ from the MDEA process combined with the $H_2S$ from the DEA treating and sour water strippers becomes the feed to the Sulphur Plant. The proposed Sulphur Plant facilities consist of three 50 percent capacity Claus Units.

Each of the proposed Claus Plants (see Figure 4) consists of thermal conversion, and three stages of catalytic conversion, in series. The thermal conversion step has provision for separate combustion of the ammonia rich stream from the sour water stripper with excess air to ensure the complete destruction of $NH_3$.

The chemical reaction:

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O$$

is the basis by which $H_2S$ is converted to sulphur in the Claus Plant.

To provide the $SO_2$ for this reaction the acid gas, containing $H_2S$, enters the reaction furnace where 1/3 of the $H_2S$ is burned with a controlled amount of air. The burning produces the stoichiometric amount of $SO_2$ for the subsequent conversion of $H_2S$ and $SO_2$ to sulphur.

The combustion reactions are highly exothermic. The hot gases produced pass through a waste heat boiler to generate steam. As the gases are cooled, the sulphur formed in the reaction furnace condenses and is removed to storage. After the condensation step; the remaining gas containing $H_2S$ and $SO_2$ is reheated, catalytically reacted, and cooled to remove additional sulphur. This process is repeated three times, once in each of the three reactors operating in series.

The molten product sulphur will be pumped as required for transport to market or to the storage block where it cools and solidifies. Prior to pumping, the sulphur goes through a continuous degasification process to strip the dissolved sulphides down to 10 ppm from a typical level of 200-700 ppm. The sweep gas and the evolved $H_2S$ are vented to the onsite Sulphur Plant incinerators. This degassing step will avoid any potential odour problems from the sulphur storage block.

The Claus Units are designed for minimum recovery efficiency of 96.0 percent. It is planned to operate with all three 50 percent units on line. The design efficiency can, therefore, be maintained even during the loss of any one unit since the total feed can be distributed to the remaining two units.

(iii) Tail Gas Clean-up

The tail gases leaving the Claus Units are directed, for further recovery of $H_2S$, to two 50 percent capacity hydrogenation/absorption Tail Gas Cleanup Units (TGCU). In the hydrogenation step the sulphur compounds are converted catalytically to $H_2S$. In the absorption stage, MDEA is again used to selectively extract the $H_2S$ from the tail gas. The rich amine solution is returned to the MDEA regeneration facilities associated with the low Joule gas treating system for common stripping of the solvent. The gases leaving the TGCU Units are routed to incinerators for conversion of any remaining sulphur compounds to $SO_2$ prior to discharge to a stack.

The TGCU Units are designed for a sulphur recovery efficiency of 96.0 percent. When combined with the Claus Plants, a minimum overall sulphur recovery of 99.8 wt. percent is attained. At this recovery, the $SO_2$ emission contribution from the sulphur recovery facilities is only 4.6 t/d as shown in Table 2. In the event of a loss of one TGCU Unit, the emissions of $SO_2$ from sulphur recovery rise

to 46.3 t/d. This, together with other emission sources from the combustion of fuels results in a total emission of 119.7 t/d or 4.7 t $SO_2/10^3m^3$ bitumen vs the guideline of 4.8 t $SO_2/10^3m^3$ for upset conditions.

(iv) Disperson of $SO_2$ Emissions - Stack Design

The total sulphur dioxide emitted from the Project, including that generated from incineration of the sulphur recovery tail gases and combustion of various fuels, is dispersed via several stacks ranging in height from 76 to 122 metres.

The current design proposes a total of seven stacks (six at Plant 1 and one at Plant 2). One stack at Plant 1 serves the utility boiler, one serves the steam generators, one stack is located on each Upgrader train and two stacks are associated with the Tail Gas Cleanup Units. At Plant 2 the flue gases from all the steam generators are ducted to one common stack.

The stacks have been designed according to the "Guidelines for Plume Dispersion Calculations" and the "Stacks" computer program issued by Alberta Environment in August 1978. The stacks have been designed to achieve ground level concentrations well below the standards even under upset conditions.

At the emergency guideline emission (4.8 t $SO_2/10^3m^3$ of feed or 135.4 tonnes per stream day) the calculated maximum 1/2 hr. $SO_2$ concentration at a tree canopy height of 25 metres is 400 $ug/m^3$ (0.15 ppm). Under normal operations the maximum 1/2 hr. $SO_2$ concentration is 175 $ug/m^3$ (0.07 ppm). The Alberta standard for a 1/2 hr. averaging time is 525 $ug/m^3$ (0.2 ppm).

(v) Potential Impacts of $SO_2$ Emissions

Annual average ground level concentrations of $SO_2$ were determined using the Climatological Dispersion Model (CDM) developed by the U.S. Environmental Protection Agency. This model was previously used by Walmsley and Bagg[4] for studies in the Alberta oil sands area. Their calculations were reasonably well correlated with available observational data and they concluded that the model is adequate for computing seasonal or annual average concentrations of sulphur dioxide at ground level.

The isopleths shown in Figure 5 were calculated assuming normal emissions of $SO_2$ during 95 percent of the year with the emergency level of emissions during the remaining 5 percent for a daily average emission of 80.1 t/d. It is noted that the isopleths are skewed to the east-west because of the higher frequency of winds in those directions. The maximum annual average concentration of about 1.5 $ug/m^3$ is

predicted to occur over a small area within about 7 miles (12 km) of the Plant 1 site. Beyond about 25 miles (40 km) to the east, the concentration is predicted to decrease to 0.75 $ug/m^3$.

The annual average $SO_2$ concentrations as determined above were then used to estimate the total dry deposition of sulphur: The following relationship described by Walmsley and Bagg[4] was used.

$$D = 0.5\, q\, U_d\, t$$

where:
- $D$ = sulphur Deposition
- $q$ = sulphur dioxide concentration
- $U_d$ = deposition velocity
- $t$ = time period of deposition

A deposition velocity of 1 cm/s was assumed.

The results are recorded on the isopleth map Figure 5. The maximum predicted deposition is approximately 3 kg/ha/year or 75 kg/ha over the 25 year life of the Project.

The potential impacts of sulphur dioxide emissions can include:

- o acute vegetation damage due to short-term high ground level concentrations, and
- o the longer term accumulation of sulphur deposits and the effects of lowering soil pH and modification of soil nutrient status.

A thorough review of the literature, however, has indicated that incidents of vegetation damage should not occur, nor is the level of sulphur addition sufficient to have any significant effect on the soil chemistry over the life of the Project.

## B. Other Stack Emissions

Nitrogen oxides are produced during combustion processes in the Flexicoker, process furnaces and utility boilers. Also trace amounts of CO will be present in the combustion gases. The quantities produced are a function of the fuel combustion environment and the control system. The estimated 1 hr. glc's are well below the ambient air quality standards.

## C Particulate Emissions

The FLEXICOKER includes extensive provisions to control potential emissions of coke dust (Figure 6). The low Joule gas first passes through internal cyclones in the heater vessel to remove the bulk of the entrained coke. The stream then passes though an external

tertiary cyclone separator and venturi scrubbers before being introduced into the MDEA absorber. The overhead from the absorber is then distributed as a particulate free low Joule gaseous fuel.

The FLEXICOKER also includes provision for coke storage in a coke silo for inventory control during normal operations as well as startup and shutdown requirements. The transfer of coke is accomplished pneumatically using air as the carrier. The carrier air leaving the coke silo will pass through bag filters (or equivalent) to reduce the particulates to less than 0.2 kg/t prior to discharge to the atmosphere.

The two sources of purge coke, i.e. tertiary cyclone fines and venturi scrubber slurry, will be mixed to maintain a moist purge stream for disposal in a landfill.

Particulates (fly ash) resulting from the burning of coal will be removed by electrostatic precipitators designed to ensure that the allowable maximum emission of 0.2 kg/t of flue gas is achieved. An estimated 12-15 t/d of fly ash would enter the atmosphere.

D Hydrocarbons

The project will be designed such that there will be no continuous venting of hydrocarbons. For example, the production gases vented from the casing annulus during pumping operations will be recovered at each satellite. The present design provides for cooling, scrubbing and compression/pumping of these fluids into the group production facilities.

Approximately 477 x $10^3 m^3$ (3.0 million barrels) of tankage will be provided for storage of water, bitumen, intermediate products, upgraded crude, butane and miscellaneous chemicals.

The hydrocarbon tankage will be designed on the basis that:

- All tanks with a diameter exceeding 15 m (50 ft.) and holding stocks with a vapour pressure of 21-83 kPa (3-12 psi) will be provided with a floating roof designed with seals to close the space between the roof edge and the tank wall.

- All stocks with vapour pressures in excess of 83 kPa will be stored in closed drums or pressure spheres.

Discharge of safety relief valves will be preferentially tied into the flare system. Where this is not practical, additional steps will be considered to minimize the discharge to atmosphere, e.g. additional instrumentation to minimize the probability of a release or providing a smaller release to the flare at a lower set pressure than the parallel main release to atmosphere.

E. Odours

As in conventional refineries, localized odours can be expected from the Project operation. Odours can arise from storage tanks, separators, settling ponds, safety valve discharges, minor leaks from pump seals, valve packings, etc.

All known materials or sources causing potential odour problems, however, will be confined or deodourized by absorption, scrubbing, flaring or incineration before release.

F. Smoke

Smoke emissions will be controlled by proper combustion control of boilers and by provision of special flare stack tips to promote complete combustion.

G. Flare Design

The current design visualizes a 61 m (200 ft.) high flare at each Fieldgate i.e. one at Plant 1 and one at Plant 2. In addition, one flare approximately 122 m (400 ft.) is projected for each train of the Upgrader. The two Upgrade flares will probably be located on a common derrick structure with provision for individual lowering for flare tip maintenance.

The flare heights have been calculated in accordance with the "Guidelines for Plume Dispersion Calculations", published by the Alberta Department of the Environment, August, 1978.

The design features of the flare system include:

- Sufficient height to achieve an $SO_2$ ground level concentration of less than 0.2 ppm (1/2 hr. average) when flaring sour gases at the highest anticipated rate.
- Provision to automatically introduce auxiliary fuel when flaring $H_2S$ to ensure complete combustion.
- Flow measuring devices in the main laterals.
- Sufficient steam capacity to ensure smokeless operation under all reasonably probable contingencies including any planned startup/shutdown operations.

H. Noise

Facility design criteria to be utilized stipulate that noise shall not be greater than 50 dBA at the Esso Resources lease boundary and noise from the Upgrader shall not be greater than 55 dBA at the Upgrader site boundary. In order to minimize noise from Project facilities, sound absorbing walls, mufflers and quiet machinery will be employed where practicable.

A number of cottagers exist within the lease boundary. Some operational restrictions with respect to selective drilling schedules may be required to avoid any potential impacts.

I. Fog

Large volumes of water vapour are released to the atmosphere from combustion processes, cooling towers and water holding ponds. The addition of this water to the atmosphere increases the potential for water fog and ice fog production in the region.

According to Murray and Kurtz[5] extensive ice fogs are generally experienced only during sustained periods of temperatures below -40°C. Over the 15 year period 1956-1970, these temperatures were recorded on average of only about 0.3 percent of the time (2-3 hours) during January, the coldest month at Cold Lake. In addition, the topography of the area allows better dispersion characteristics than other areas, such as Fairbanks, Alaska, where ice fogs have been of considerable concern.

The probability of significant ice fog formation having widespread impact in the region due to the proposed operations at Cold Lake is, therefore, expected to be very remote. Localized impacts in the vicinity of the plant can be expected and will be considered, for example, in locating the cooling towers relative to other plant facilities.

An additional area of concern is the potential interaction of fog and pollutants. Croft et al[6] for example, indicate that heavy metals may catalyze the oxidation of sulphur dioxide and that fogs may occur more frequently because of additional condensation nuclei. The strong temperature inversions which are characteristic during these fogs, however, will not allow the high level stack sources which contain most of the Project emissions to reach ground level to react with fog.

## MONITORING

Plant emissions as well as ambient air quality will be measured in order to control and monitor the impact on air quality.

A. Emission Monitoring

The various stacks will be equipped with continuous monitors for $SO_2$, flue gas flow and temperature. These data will be fed to a computer to provide a real time display of total plant $SO_2$ emissions.

Equipment designed to burn solid or liquid fuels will be equipped with smoke detectors (opacity instruments) to ensure proper combustion.

The main flare laterals will be provided with flow sensors to aid in controlling unwanted hydrocarbon releases to the flare. Each flare will also be equipped with closed circuit TV monitors to assist in control of smoke emissions.

In addition to continuous monitoring of stack emissions, each stack will be provided with spare sampling ports and permanent ladders and platforms to allow for periodic surveys as required by the Stack Sampling Code.

## B. Ambient Air Quality Monitoring

It is proposed to provide two continuous ambient air quality monitoring stations. Each station would be provided with instruments to monitor for $SO_2$, $H_2S$, hydrocarbons and $NO_x$. Current planning is to retain one station in a permanent location while the other may be moved as desired. The station locations will be determined with the help of dispersion calculations once the plant emission distribution is finalized.

Meteorlogical measurements including wind speed and direction, temperature and precipitation will also be undertaken at each continuous air monitoring location.

All ambient air data will be transmitted to a central computer for recording and/or display.

In addition to the continuous monitors, a network of sulphation cylinders to monitor $H_2S$ and $SO_2$ will be provided.

Measurement for potential odour or noise sources will be undertaken on a spot basis should unexpected situations arise.

## C. Soils

Esso Resources has undertaken a program to monitor, over the life of the Project, the sulphur levels in the soil within a 50 km radius of the plant.

The first part of the program will begin during summer 1979 and is intended to provide our researchers with chemical information on both the present levels of sulphur in the soils and on the capacity of the soils to receive additions of sulphur without detrimental effects. Approximately 80 sampling sites have been selected representing the range of soil types found within 50 km of the plant. Although all soil types in the region will be sampled, including those in forested areas, the majority of the samples will be taken from agriculturally important soils.

The permanent sites selected will be representative of the soils in the region with emphasis on any soils identified in the first phase of the program which may be sensitive to sulphur additions. It is expected that 20 to 40 of the original 80 sites will be selected as permanent monitoring sites.

In addition, pots of a prepared soil will be placed at selected sites. Because sulphur additions from the plant are expected to be small, natural fluctuation in soil sulphur levels may mask changes due to $SO_2$ emissions. The pots of prepared soils will reduce the effects of natural fluctuation and increase the accuracy with which any additions from the plant can be measured.

D. Vegetation Monitoring

Baseline information is required regarding present vegetation status using plants most sensitive to sulphur dioxide (arboreal lichens) as the indicator of vitality. A system of sampling sites will be placed around the proposed plant in close proximity to soil monitoring sites. The health and vigor of the plants will be examined.

In the vicinity of each site the overall condition of the vascular vegetation will also be noted. Causes of vegetation injury such as insect infestations, fire, and changes in water table will be recorded.

The selected sites will be surveyed periodically throughout the life of the project.

E. Effects of Sulphur on Selenium Uptake by Forages

White Muscle Disease is a condition which may occur when cattle feed on selenium deficient forage and selenium has been shown to be sporadically deficient in forages from some areas near Cold Lake. Since soil sulphur has been identified in the literature as one factor influencing selenium availablity to plants, soil sulphur additions resulting from the proposed plant may influence the availability of selenium in the forages from these areas. It has been shown that it may be difficult to accurately predict selenium deficiencies in forages on the basis of soil analyses. Therefore, to assess the initial magnitude of this problem and possibly locate areas which might be sensitive to sulphur additions, samples of domestic and wild forage will be collected and analyzed prior to plant startup for total selenium content. The results of these analyses may indicate areas where selenium in forages should be monitored after the plant begins operation.

# REFERENCES


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2. "Final Environmental Impact Assessment. Cold Lake Project", Volume II - Bio Physical Resources Impact Assessment, October, 1979.

3. J.F. Skrabec, J.C. Kempling, J.S. Mullen, "Paper No. 47 - Process Selection Considerations in the Upgrading of Cold Lake Bitumen" Presented to Unitar Conference, Edmonton, Alberta, June, 1979.

4. J.L. Walmsley and D.L. Bagg, "Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area", AOSERP Project ME4.1, 1977.

5. W.A. Murray and J. Kurtz, "A Study of Potential Ice Fog and Low Temperature Water Fog Occurence at Mildred Lake, Alberta", Environmental Research Monograph 1976-4, Syncrude Canada Ltd., Edmonton, Alberta.

6. B.R. Croft, A. Lamb and R.N. Dawson, "A Preliminary Investigation into the Magnitude of Fog Occurence and Associated Problems in the Oil Sand Area" AOSERP Project ME3.3, 1977.

## TABLE 1

## COLD LAKE PROJECT

## SULPHUR BALANCE
t S/d

| | | |
|---|---|---|
| **SULPHUR IN** | | |
| Bitumen | | 1,134 |
| Coal | | 11 |
| Production Off-Gas | | 10 |
| | TOTAL | 1,155 |
| **SULPHUR OUT** | | |
| Upgraded Crude | | 13 |
| Elemental Sulphur Product | | 1,074 |
| Predicted Sulphur Emissions | | 39 |
| Fly Ash | | 3 |
| Purge Coke | | 3 |
| Sour Water to Deep Well Disposal | | 23 |
| | TOTAL | 1,155 |

TABLE 2

PREDICTED SULPHUR DIOXIDE EMISSIONS
t $SO_2$/d*

| SOURCE | UPSET CONDITIONS | NORMAL CONDITIONS |
|---|---|---|
| Production Off-Gas | 19.4 | 19.4 |
| Light Ends | 11.3 | 11.3 |
| Low Joule Gas | 26.1 | 26.1 |
| Sulphur Plant | 46.3** | 4.6 |
| Supplementary Liquid Fuel | 0.7 | 0.7 |
| Balancing Fuel | 15.9 | 15.9 |
| TOTAL | 119.7 | 78.0 |
| Overall Sulphur Plant Efficiency, Percent | 97.9 | 99.8 |
| $SO_2/10^3m^3$ Bitumen | 4.7 | 3.1 |
| Target Maximum Emissions | 4.8 | 3.2 |

* Divide values by 2 to obtain tonnes sulphur per day (t S/d). Emissions shown are per calendar day.

** The upset condition depicted is the loss of one of the Tail Gas Cleanup Units.

FIGURE 1

# COLD LAKE PROJECT SCHEMATIC

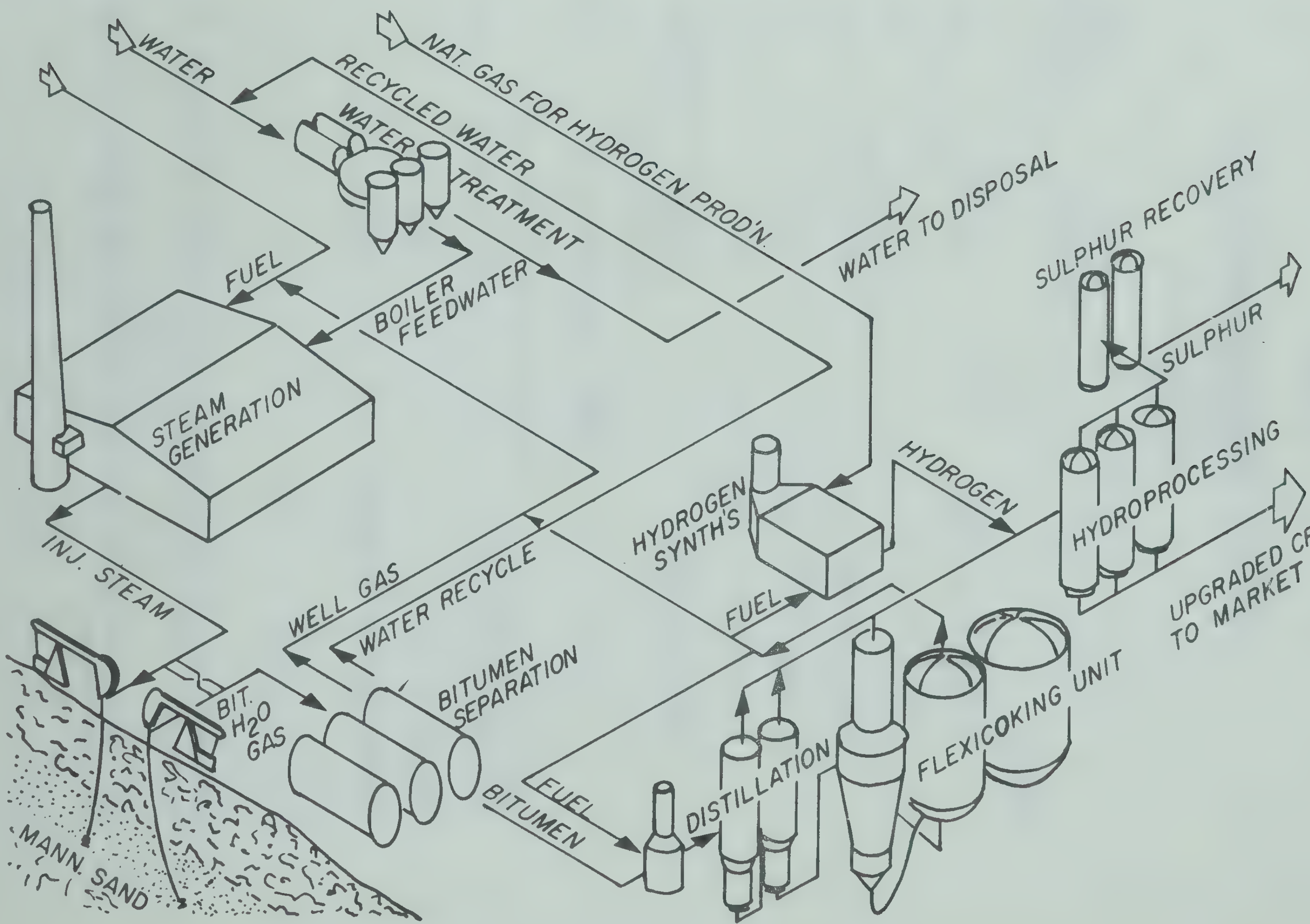
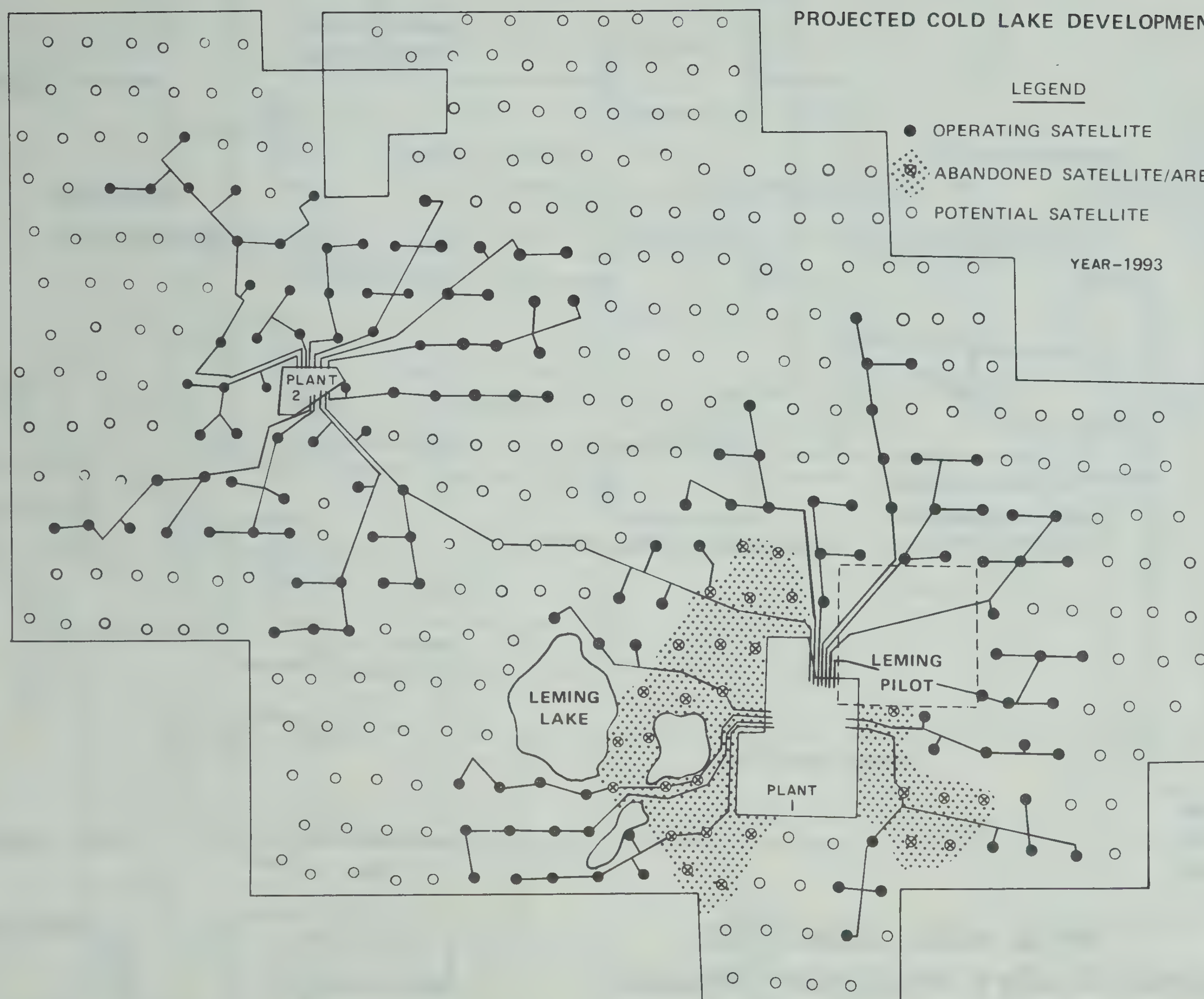


FIGURE 2

**PROJECTED COLD LAKE DEVELOPMENT**




LEGEND

OPERATING SATELLITE

ABANDONED SATELLITE/AREA RECLAIMED

POTENTIAL SATELLITE

YEAR-1993

FIGURE 3

## SULPHUR REMOVAL AND RECOVERY FACILITIES
## SIMPLIFIED FLOW PLAN

$H_2S$ – HYDROGEN SULPHIDE
$SO_2$ – SULPHUR DIOXIDE
$NH_3$ – AMMONIA

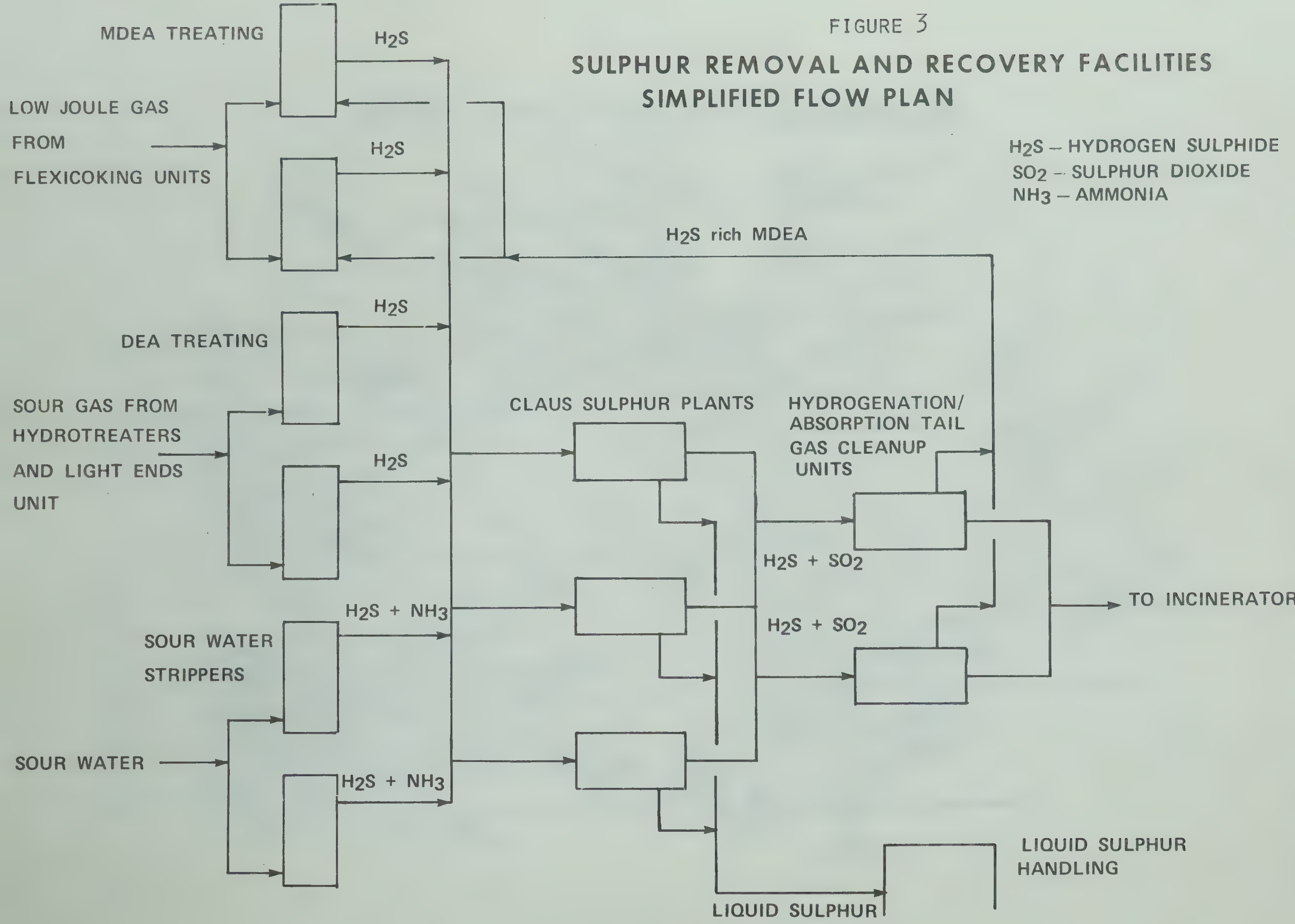
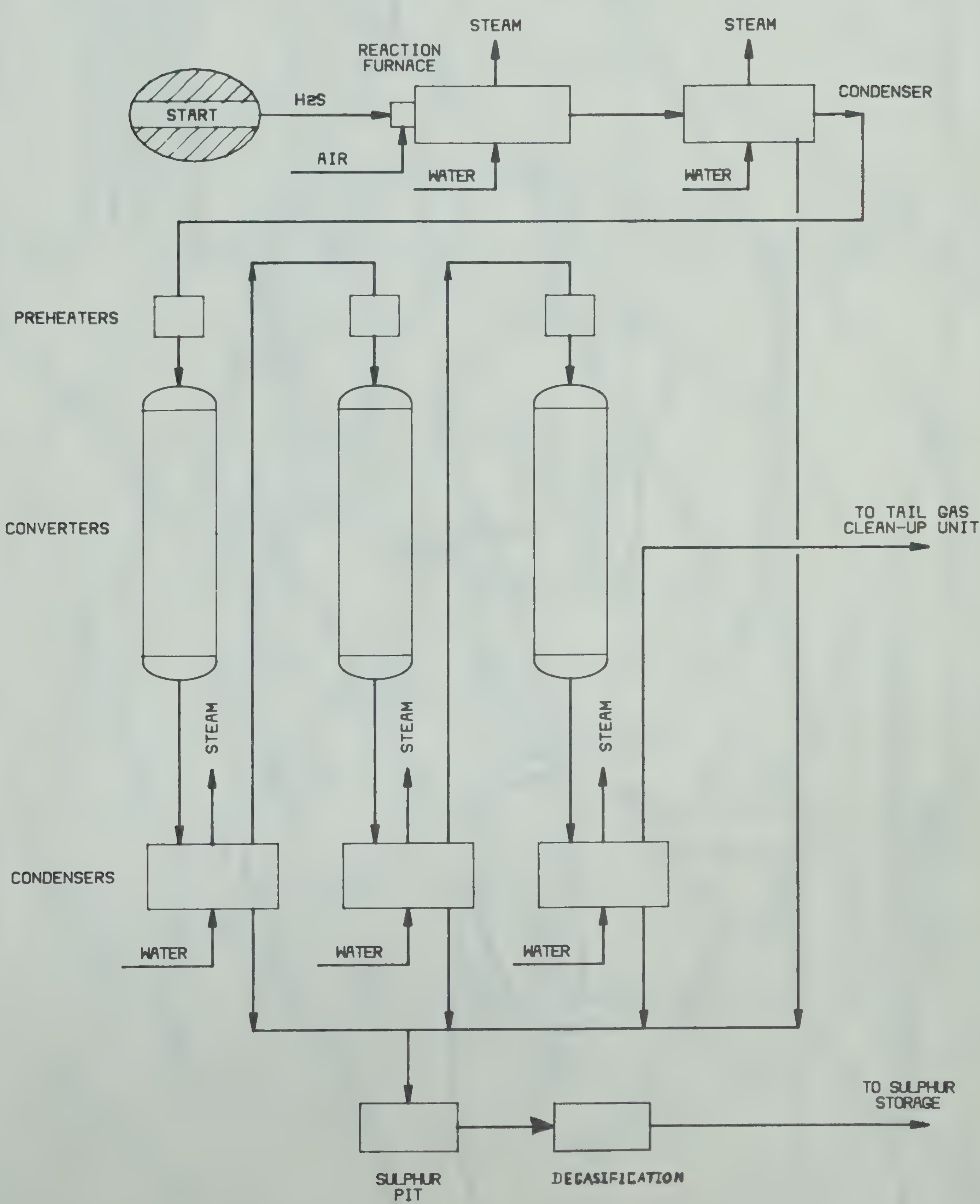


FIGURE 4

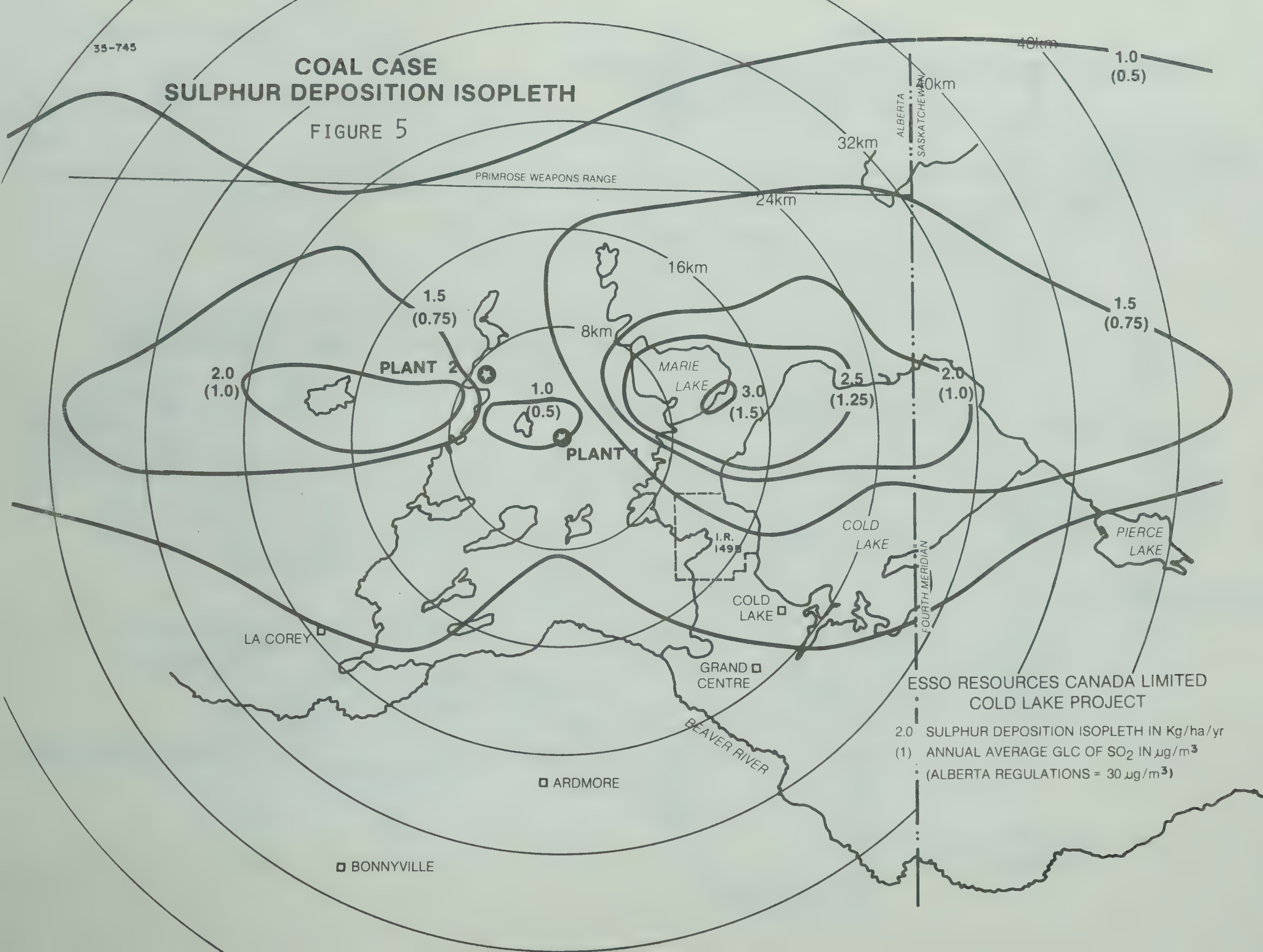
CLAUS SULPHUR PLANT
SIMPLIFIED FLOW DIAGRAM



35-745

# COAL CASE
# SULPHUR DEPOSITION ISOPLETH

FIGURE 5




ESSO RESOURCES CANADA LIMITED
COLD LAKE PROJECT

2.0 SULPHUR DEPOSITION ISOPLETH IN Kg/ha/yr
(1) ANNUAL AVERAGE GLC OF $SO_2$ IN $\mu g/m^3$
(ALBERTA REGULATIONS = 30 $\mu g/m^3$)

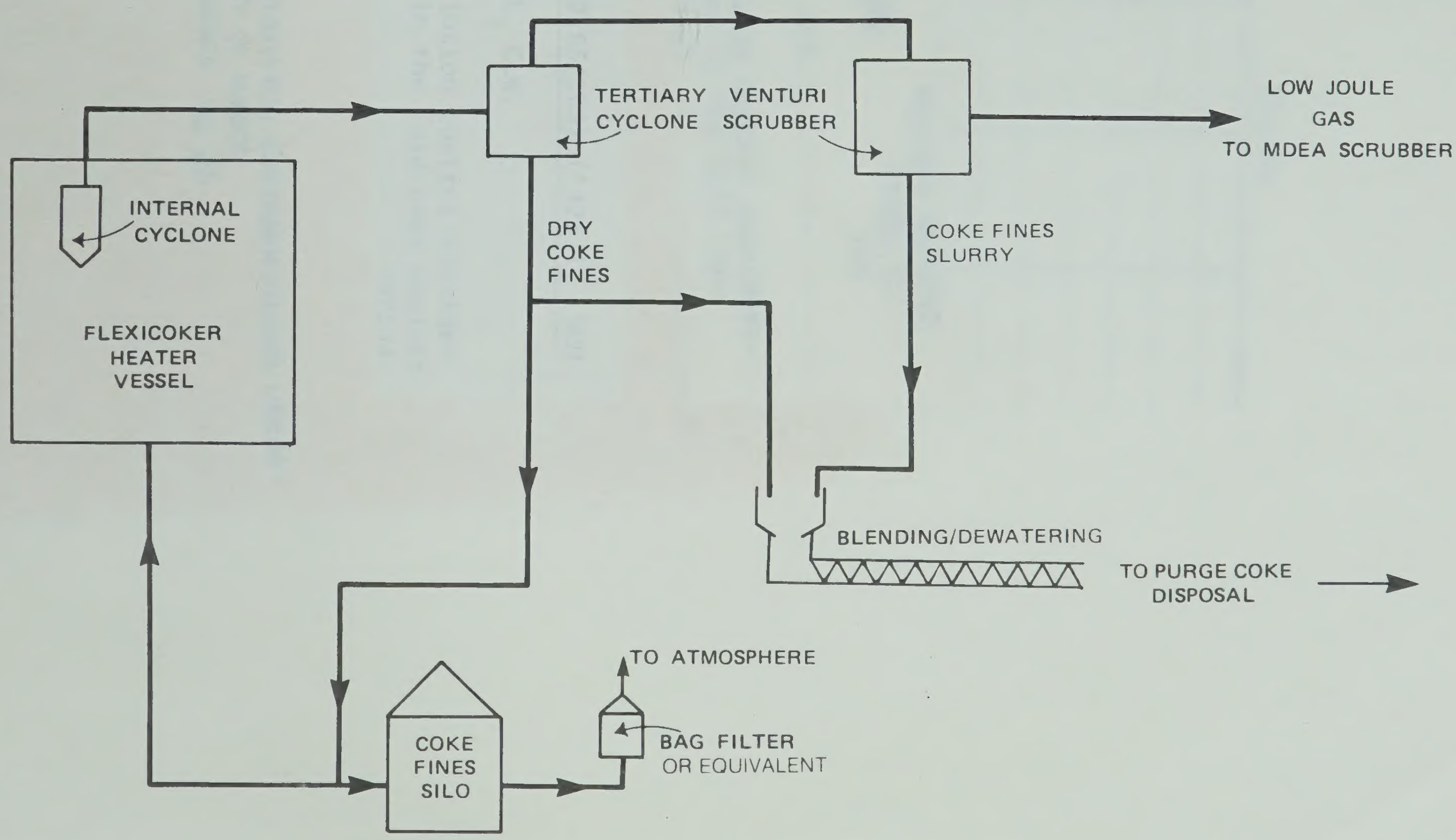



FIGURE 6

COKE PARTICULATE CONTROL SYSTEM

COAL CASE
SULPHUR DEPOSITION ISOPLETHS